European Master in Advanced Solid Mechanics

Politechnika Wrocławska

The Wroclaw University of Science and Technology

Module handbook for Semester 3

10 ELECTIVE MODULES		
1	Risk Assessment in Geotechnics – Implementation of Random Field Theory	5 ECTS
2	Mathematical Homogenizations and Micromechanics	5 ECTS
3	Advanced Geoengineering	5 ECTS
4	Advanced steel-concrete Composite Constructions	5 ECTS
5	Advanced Soil Mechanics and Soil-Structure Interaction	5 ECTS
6	Fracture Mechanics	5 ECTS
7	Laboratory Identification of Composite Micostructure Properties	5 ECTS
8	Advanced Nano-Materials	5 ECTS
9	Reliability and Maintenance Theory and Engineering	5 ECTS
10	Inventive Engineering	5 ECTS

The student has to choose 6 modules among the 10 elective modules listed above.

Module #1	**RISK ASSESSMENT IN GEOTECHNICS — IMPLEMENTATION OF RANDOM FIELD THEORY**			
Information	<u>Credit Points :</u> 5 ECTS	<u>Workload :</u> 60h	<u>Mode :</u> Elective module	<u>Offered :</u> 3rd semester
Institution in charge	Wrocław University of Science and Technology			
Instructors	W. Puła, M. Chwała, J. Pieczyńska-Kozłowska			
Contents	General comments on uncertainty in geotechnical analyses. Sources and types of uncertainty in geomechanical properties. Stochastic processes and random fields – basic theory. Common random fields models. Probabilistic modelling of geomechanical properties. Spatial averaging. Correlation radii. Linear regression. Best linear unbiased estimation. Geostatistics -Kriging. Basics of simulation. Simulation of random fields. Outline of structural reliability. Examples of reliability assessments to various geotechnical problems. The stochastic finite element method (SFEM) and random finite element method (RFEM). An overview. RFEM application to shallow foundation settlement, earth pressure problem and slope stability analysis. Reliability based design. Examples of risk assessments.			
Examination	Each student will receive a problem to solve using software available in the laboratory. The way of solving will give 70% of the final grade. The 30% will be given for the theoretical knowledge after oral discussion with the instructor.			
Requirement for examination	Each student has to prepare a report on a solution of certain problem obtained at the beginning of the course.			
Learning outcomes	On successful completion of the course, students will be able to: • understand the basic concept of the random fields theory and its application to characterization of soil properties spatial variability; • understand a basic ides of kriging and has some skill in using kriging's software; • operate software dedicated to reliability assessments available in the form of spreadsheets form; • understand the basic ideas of stochastic finite element method and its applications; • understand how the reliability approaches can be used in a design process.			

<table>
<tr><td>Module #2</td><td colspan="4">MATHEMATICAL HOMOGENIZATION AND MICROMECHANICS</td></tr>
<tr><td>Informations</td><td><u>Credit Points :</u>
5 ECTS</td><td><u>Workload :</u>
60h</td><td><u>Mode :</u>
Elective module</td><td><u>Offered :</u>
3rd semester</td></tr>
<tr><td>Institution in charge</td><td colspan="4">Wrocław University of Science and Technology</td></tr>
<tr><td>Instructors</td><td colspan="4">Dariusz Łydżba, Adrian Różański</td></tr>
<tr><td>Contents</td><td colspan="4">Principles of mathematical homogenization theory; H-convergence, two-scale convergence, γ-convergence. Method of asymptotic developments: linear elasticity problem, heat flow problem. Evaluation of effective properties of composite with periodic microstructure. Numerical implementation of periodic boundary conditions. Principles of micromechanics. Computational and analytical methods. Analytical methods: Eshelby solution of single inclusion problem, bounds on effective properties. Analytical methods: Maxwell approximation scheme, Mori-Tanaka approximation scheme, Self-Consistent approximation scheme, Differential Effective Medium approach. Analytical methods: concentration parameter, average shape, equivalent microstructure approach. Computational micromechanics: statistical microstructure descriptors, size of Representative Volume Element. Computational micromechanics: Principles of Monte Carlo simulations, sufficient number of realizations (Central Limit Theorem, Chebyshev's Inequality). Computational micromechanics: numerical methods – Finite Volume Method, Finite Element Method. Estimation of effective properties based on digital image of microstructure: linear elasticity and heat flow problems.</td></tr>
<tr><td>Examination</td><td colspan="4">Written final exam</td></tr>
<tr><td>Requirement for examination</td><td colspan="4">No specific requirement</td></tr>
<tr><td>Learning outcomes</td><td colspan="4">On successful completion of the course, students will be able to:
● Evaluate bounds on effective properties with respect to elastic and thermal properties;
● Compute effective properties of random media with the use of homogenization approximation schemes;
● Solve simple problems of micromechanics in the framework of numerical methods.</td></tr>
</table>

Module #3	ADVANCED GEOENGINEERING			
Information	Credit Points : 5 ECTS	Workload : 60h	Mode : Elective module	Offered : 3rd semester
Institution in charge	Wrocław University of Science and Technology			
Instructors	J. Pieczyńska-Kozłowska			
Contents	As part of the course, students obtain information on a wide range of methods for strengthening the soil and creating contact surfaces between the structure and the soil. Students will be led through a spectrum of foundation methods from direct foundation through soil reinforcement methods to indirect geotechnical structures. In part, the course will be devoted to modern geotechnical technologies used in the process of producing energy from renewable sources. The special case considered as part of the course program will be the foundation of special facilities such as i.e. wind turbines, energy piles or tunnels.			
Examination	Oral exam where student will be ask to answer to a few of questions regarding the main concepts presented in the course (30% of final mark). Individual work during semester (e.g. to prepare simple calculations to read and present orally a given topic) counts for the other 70%.			
Requirement for examination	No specific requirement			
Learning outcomes	Distinguish and classify the different classes of foundation methods depending on the type of construction (linear, bridge, cubature). Obtains expanded knowledge in the field of modern technologies for strengthening the subsoil and intermediate foundations. Introduce the student to the multidisciplinary topics of renewable sources of energy in context of geotechnics structures Solve simple problems using the models derived during the lectures as well as the new concepts discovered in this course. Acquire knowledge of technologies and procedures for the implementation of complex geotechnical structures such as reinforced soil, retaining walls, soil and coating structures, etc. Student will gain knowledge of the impact of vibration caused by geotechnical works on various types of objects.			

	After successful completion of the course, students will be able to: • design various of geotechnical structures and will have the opportunity to participate in the implementation process as part of cooperation with an industry partner; • select the appropriate technology based on material characteristics and soil and water conditions; • interpret and use in design knowledge resulting from the results of geotechnical studies; • demonstrate the ability to analyze the implementation process of complex geotechnical structures such as reinforced soil, retaining walls, soil and coating structures, etc; • be aware of the need to expand knowledge in the field of contemporary design techniques and geotechnical constructions; • obtain the ability to prepare presentations about renewable sources and geotechnical problems.

Module #4	ADVANCED STEEL-CONCRETE COMPOSITE CONSTRUCTIONS			
Informations	Credit Points : 5 ECTS	Workload : 60h	Mode : Elective module	Offered : 3rd semester
Institution in charge	Wrocław University of Science and Technology			
Instructors	Wojciech Lorenc, Maciej Kożuch, Piotr Kozioł			
Contents	The aim of the course is to familiarize participants with the theory of composite steel and concrete structures, analysis methods, industry experiences and with the latest achievements and progress in the field. The development of composite structures and methods of their analysis will be discussed: history, present day and predictable future. In addition, specific aspects will be presented in the field of building mechanics, strength of materials and steel constructions constituting the necessary workshop in the analysis and construction of advanced composite steel and concrete elements. Methods of modeling, in particular FEM, and experimental methods will be discussed. The specifics of contemporary R&D works leading to the implementation of structures on the European market will be presented. In addition, the specifics of design and implementation will be presented.			
Examination	Written final exam			
Requirement for examination	No specific requirement			
Learning outcomes	At the end of the course, the student should be able to: • understand basic principia for standard composite structures and modern general composite sections; • make FE models of composite structures; • design composite elements and in particular shear connection using welded studs and composite dowels; • distinguish the new composite forms on the background of standard ones.			

Module #5	**ADVANCED SOIL MECHANICS AND SOIL – STRUCTURE INTERACTION (CE)**			
Information	Credit Points : 5 ECTS	Workload : 60 h	Mode : Elective module	Offered : 3rd semester
Institution in charge	Wrocław University of Science and Technology			
Instructors	M. Kawa, S. Sobótka			
Contents	Specifics of the soil medium: classifications physical and mechanical properties. Stress and deformation tensors. Concept of effective stress. Darcy's Law, seepage force, permeability Test. Groundwater flow in saturated and unsaturated soil. Constitutive relations for deformation problems in soils. Models of the substrate. Analytical and numerical solution for elastic half-space. Consolidation problem. Plasticity of the soil: Mohr-Coulomb model. Direct shear test. Triaxial test. Retaining structures. Earth pressures. Stability of slopes. Analytical and numerical methods. Shear strength reduction method. Limit theorems. Finite element limit analysis. Application of numerical methods in analyses of geotechnical problems. Hydro-mechanical coupled problems. Specifics of soil - structure interaction. Strip foundations, shallow and deep tunnels, deep excavations. Modelling of contact zone between soil and the structure. In-situ soil testing. Designing and interpretation of tests of the soil.			
Examination	Written exam (60% of final mark). Individual work during semester (shor reports from computer lab) counts for the other 40%.			
Requirement for examination	No specific requirement			
Learning outcomes	On successful completion of the course, students will be able to: • understand the specifics of soil medium; • design and interpret laboratory and in-situ tests of the soil; • determine the state of stress as well as elastic and plastic deformations of the soil; • apply limit state theory; • apply numerical methods in designing earthen structures; • utilize adequate model of soil-structure contact in numerical computations.			

Module #6	**FRACTURE MECHANICS**			
Information	Credit Points : 6 ECTS	Workload : 60h	Mode : Elective module	Offered : 3rd semester
Institution in charge	Wrocław University of Science and Technology			
Instructors	Grzegorz Lesiuk			
Contents	The course aims to introduce to students the fracture mechanics of brittle and ductile materials. The lectures will focus on the fundamentals of linear-elastic crack mechanics (LEFM) and elastic-plastic fracture mechanics (EPFM) parameters, including J-Integral. The proposed course is focused on the topics related to the practical aspects of fracture and fatigue, structural integrity and lifetime calculation solutions of engineering materials and structures (metallic, composite, joints, etc.) – especially subjected to cyclic loading.			
Examination	Written final exam			
Requirement for examination	No specific requirement			
Learning outcomes	After completion of the course, the student: • knows the fundamentals of fracture mechanics; • is able to calculate the critical load of cracked components/critical defect size for a given load level; • is able to predict the precritical fatigue crack growth lifetime; • is able to measure fracture resistance of materials; • knows the rules of the damage tolerance philosophy.			

Module #7	LABORATORY IDENTIFICATION OF COMPOSITE MICROSTRUCTURE PROPERTIES			
Information	Credit Points : 5 ECTS	Workload : 60h	Mode : Elective module	Offered : 3rd semester
Institution in charge	Wrocław University of Science and Technology			
Instructors	Dariusz Łydżba, Adrian Różański			
Contents	Physical foundations of X-Ray computed tomography. Mathematical foundations of X-Ray computed tomography: Radon transform, Reconstruction procedure (Feldkamp algorithm). Statistical descriptors of digital representation of microstructure: volume porosity, fraction of open and closed pores, pore size distribution, pore shape distribution, tortuosity. Principles of nanoindentaion tests: loading paths, evaluation of indentation depth, area of imprint. Nanoindentaion tests: theoretical aspects – Sneddon solution. Grid Indentation Technique; histograms, segmentation. Sequential Indentation Technique; complex load paths, scales of observation, identification of scale effect. Usefulness of nanoindentation technique – practical aspects. Identification of carbonation zone in concrete, durability of crystalline phase in concrete microstructure modified by the mineral powders. Principles of Scanning Electron Microscopy (SEM). SEM: evaluation of surface morphology descriptors. Combined use of *X*-Ray microCT, nanoindentation tests, SEM for evaluation of composite microstructure properties: geomaterials, concrete, scaffold.			
Examination	Exam: oral (50% of final mark). Individual work during semester (e.g. preparation of reports and presentations) counts for the other 50%.			
Requirement for examination	No specific requirement			
Learning outcomes	On successful completion of the course students will be able to: ● describe the microstructure of random materials in terms of theory of probability; ● prepare full research program for geometrical microstructure identification with the use of available laboratory techniques; ● prepare full research program for mechanical microstructure identification with the use of available laboratory techniques.			

Module #8	ADVANCED NANOMATERIALS			
Informations	Credit Points : 5 ECTS	Workload : 90h	Mode : Elective module	Offered : 3rd semester
Institution in charge	Wrocław University of Science and Technology			
Instructors	Jerzy Kaleta			
Contents	1. Metallic glasses, for instance, e.g.: amorphous and nanocrystalline Fe-based soft magnetic materials, bulk metallic glasses, hard magnetic materials, magnetocaloric materials, shape memory alloys. 2. Sol-Gel processing methods for functional materials, and in this example: oxide nanomaterials: properties and applications, sol-gel synthesis of nanomaterials , ways of nanomaterials deposition, hybrid and functionalized oxide nanomaterials, nanomaterials as interface materials, nanohybrids for energy applications, nanomaterials for cells and tissues, smart coatings for corrosion mitigations, significance of surface modification by oxide nanomaterials, oxide nanomaterials in textile industry, porosity and density of oxide nanomaterials. 2. Nanomaterials and nanostructures – methods of characterization, for instance, e.g.: spectroscopic and microscopic methods for the structural properties, approaches in mechanical studies of nanomaterials, other research methods (Raman spectroscopy, XRD diffraction), using of cross-effects for measurement techniques in nanotechnology. 3. Detailed issues and case study in the field of nanomaterials, for example: using of cross-effects for measurement techniques in nanotechnology, application of thin coatings by ultrasonic spraying, production of thin continuous large-surface layers by atomizing sol-gel hydrolysates with "nano" additives in very slow flows, nanotechnology and typical technological operations (e.g. painting, lubrication, polishing, etching), magnetostriction, electrostriction, photostriction - how to control the world "nano", when MEMS goes into NEMS - or nanomachines.			
Examination	Final written test and assessment of laboratory reports			
Requirement for examination	No specific requirement			
Learning outcomes	On successful completion of the course, students will be able to: ● describe the microstructure of random materials in terms of theory of probability; ● prepare full research program for geometrical microstructure identification with the use of available laboratory techniques; ● prepare full research program for mechanical microstructure identification with the use of available laboratory techniques.			

Module #9	RELIABILITY AND MAINTENANCE THEORY AND ENGINEERING (ME)			
Informations	Credit Points : 5 ECTS	Workload : 45h	Mode : Elective module	Offered : 3rd semester
Institution in charge	Wrocław University of Science and Technology			
Instructors	Sylwia Werbińska-Wojciechowska			
Contents	Basic concepts and definitions. Relationship between teaching supplies. Elements of machinery degradation. Characters, causes and effects of the damage.The model of irreparable component reliability. The reliability structure of unrecoverable system. Basic and simple structures. The reliability structure of unrecoverable system. Complex structures. Suitability path / Cut set. Reserving. Reliability model of repairable element. Reliability model of repairable system. Markov process. Stationary solution 2 Lec8 Markov process. Non-stationary solution Maintenace strategies. Optimization of maintenance of facilities. Maintenace strategies. Reliability Centered Maintenance. Safety of installations and technical systems. The notion of risk. Risk analysis methods: FMEA / FMECA. Risk analysis methods: FTA / ETA 2. Fundamentals of risk management methods: PHA, PSA, HAZOP. 2 Trends in development of the science of reliability and safety.			
Examination	Final written test and assessment of final project			
Requirement for examination	No specific requirement			
Learning outcomes	After completion of the course, the student: • knows know the basic methods for solving decision problems that occur during the operation of a technical object; • knows the object reliability models and the methods of risk analysis; • is able to explain the causes and effects occurring and the potential damage / disaster / hazard.			

Module #10	**INVENTIVE ENGINEERING (ME)**			
Information	Credit Points : 5 ECTS	Workload : 45h	Mode : Elective module	Offered : 3rd semester
Institution in charge	Wrocław University of Science and Technology			
Instructors	Sebastian Koziołek			
Contents	The ways of invention design with high impact on innovation. Assesment of innovations by means of objective methods. Innovation team building and methods of knowledge acquiring. Forcasting of products and services development. Conceptual design and prototyping. Planning and running of Invention workshops. Methods supporting innovation: TRIZ, Design Thinking, Syntactrics.			
Examination	Final written test and assessment of final project			
Requirement for examination	No specific requirement			
Learning outcomes	After completion of the course, the student: • knows and understand the cycle of conceptual design according to Inventive Engineering; • is able to design the product prototype and to carry out the invention sessions; • is able to generate conceptual solutions with help of heuristic methods; • is able to develop the conceptual design into final project with help of CAD system.			